Yield and Yield Components Response of Corn/Soybean Intercrop to Simultaneous Competition of Redroot Pigweed and Jimson weed

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ABSTRACT

In order to investigate the role of intercropping of corn/soybean on the resource use efficiency and suppression of weeds, a field experiment was carried out at the Faculty of Agriculture Research Farm, University of Tehran in 2006. Treatments were arranged in a factorial experiment based on a randomized complete block design with three replications. Treatments were five different mixing ratios of corn (*Zea mays*) and soybean (*Glycine max*) consisting of 100% : 0% (P_1), 75% : 25% (P_2), 50% : 50% (P_3), 25% : 75% (P_4) and 0% : 100% (P_5) . The weed infestation consisted of one weed free (W_1), and three levels of weed infestation of redroot pigweed (*Amaranthus retroflexus*) (W_2), jimson weed (*Datura stramonium*) (W_3) and a simultaneous presence of redroot pigweed and jimson weed (W_4). Weed density for both species was 15 plant m^{-1} of crop row in weed infested treatments. The

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results showed the highest yield of corn (9627.8 kg ha^{-1}) was obtained in the P_2W_1 treatment, and the lowest (3916.7 kg ha^{-1}) was in P_2W_4. But the highest yield of soybean (5050.00 kg ha^{-1}) was seen in P_5W_1 and the lowest (365.67 kg ha^{-1}) in P_2W_4. Some yield components of corn such as the kernel row number per ear , kernel number per row, and 1000 kernel weight were highest for P_4W_1, but the harvest Index was highest (0.45) for P_2W_1 and lowest (0.20) for P_4W_4. Some yield components of soybean such as pod number per plant, grain number per pod and 1000 grain weight were highest in the monoculture of soybean and the weed free treatment (P_5W_1). This treatment had the highest soybean harvest index. It could be concluded that decreasing the corn/soybean ratio in the cropping rows will increase the corn and soybean yield components. The highest weed biomass (376.73 g m^{-2}) was obtained in the monoculture of soybean infested with jimson weed and redroot pigweed. Therefore, it could be stated that corn/soybean intercropping significantly reduced the weed biomass comparing to both monocultures.

Key words: intercropping, grain corn, soybean, redroot pigweed, jimson weed, weed competition.

چکیده

به منظور بررسی نقش کشت مخلوط ذرت / سویا بر کارایی استفاده از منابع و جلوگیری از رشد علف‌های هرز ، آزمایشی در سال ۱۳۸۵ در مزرعهٔ پژوهشی دانشکده کشاورزی دانشگاه تهران واقع در کرج به صورت فاکتوریل در قالب طرح بلوک‌های کامل تصادفی با ۳ تکرار انجام شد. عوامل مورد بررسی عبارت بودند از: ۵ نسبت اختلاط دو گونه گیاه زراعی ذرت(*Zea mays*) و سویا (*Glycine max*) شامل: ۰ ٪ سویا: ۱۰۰ ٪ ذرت (P_1)، ۲۵ ٪ سویا: ۷۵ ٪ ذرت (P_2)، ۵۰ ٪ سویا: ۵۰ ٪ ذرت (P_3)، ۷۵ ٪ سویا: ۲۵ ٪ ذرت (P_4)، ۱۰۰ ٪ سویا: ۰ ٪ ذرت (P_5)، و ۴ سطح آلودگی علف‌هرز تاج خروس (*Amaranthus retroflexus*) و تاتوره (*Datura stramonium*) شامل: عاری از علف هرز (W_1)، آلوده به تاج‌خروس در تمام فصل (W_2)، آلوده به تاتوره در تمام فصل (W_3) و آلودگی توام به تاج خروس و تاتوره در طول فصل (W_4). تراکم علف‌های هرز در هر کرت ۱۵ بوته در متر از طول ردیف بود. نتایج نشان داد که بیشترین میزان عملکرد ذرت

(۹۶۲۷/۸ کیلوگرم در هکتار) در تیمار P_2W_1 و کمترین آن (۳۹۱۶/۷ کیلوگرم در هکتار) در تیمار P_4W_4 مشاهده شد. ولی بالاترین میزان عملکرد سویا (۵۰۵۰ /۰ کیلوگرم در هکتار) در تک‌کشتی عاری از علف هرز و کمترین میزان آن (۳۶۵/۶۷ کیلوگرم در هکتار) در تیمار P_2W_4 دیده شد. بالاترین میزان اجزای عملکرد ذرت مانند تعداد ردیف دانه در بلال، تعداد دانه در ردیف و وزن هزار دانه در تیمار P_4W_1 بدست آمد، در صورتی که، بالاترین میزان اجزای عملکرد سویا از قبیل تعداد غلاف در بوته، تعداد دانه در غلاف و وزن هزار دانه در تک‌کشتی سویا و در شرایط بدون علف هرز (تیمار P_5W_1) حاصل شد. این ترکیب تیماری همچنین بیشترین میزان شاخص برداشت سویا را به خود اختصاص داد. این بدان معناست که با کاهش سهم یا نسبت ذرت در مخلوط، اجزای عملکرد ذرت و سویا افزایش می‌یابد. بالاترین میزان زیست توده علف‌هرز (۳۷۶/۷۳ گرم در متر مربع) در تک‌کشتی سویا آلوده به تاتوره بدست آمد. بدین ترتیب کشت مخلوط ذرت و سویا در مقایسه با تک‌کشتی کاهش‌های معنی‌داری در زیست توده علف های هرز ایجاد نمود.

کلمات کلیدی: کشت مخلوط، ذرت دانه‌ای، سویا، تاج خروس، تاتوره و رقابت علف هرز.

INTRODUCTION

Increase in agricultural products during the 20th century was a result of high levels of external inputs (Evans, 1998). Intense agriculture, however, caused some side effects, such as soil erosion, environmental pollution by agrochemicals and fertilizers misuse, and emergence of agrochemical resistant populations of weeds and pests (Vandermeer *et al.,* 1998; Poggio, 2005).

Diversification of cropping systems by increasing the number of crop species grown in the land was known to be a solution to some problems of modern agriculture (Vandermeer, 1995; Brummer, 1998; Vandermeer *et al.,* 1998; Altieri, 1999). Intercropping (IC) known as the simultaneous growing of two or more species or cultivars on the same piece of land, is known to increase yield stability compared to sole cropping (SC), especially in low input conditions (Vandermeer, 1989; Hauggaard-Nielsen, 2006) and was presented as an option to diversify cropping systems (Brummer, 1998; Altieri, 1999). The most common reason for the adoption of intercropping is yield advantage, which is explained by the greater resource depletion by different crops than monocultures, particularly when cereal and legume crops are grown together (Vandermeer, 1989; Fukai and Trenbath, 1993; Poggio, 2006). Cereal/legume intercropping is most frequently used and productive (Carruthers *et al.,* 2000). Corn/soybean intercrops have been shown to be more productive than corn monocropping (Marchiol *et al.,* 1992). The soybean partner adds valuable nitrogen to the soil (Singh *et al.,* 1986), and improves overall protein content of the resulting silage (Martin *et al.,* 1990).

Intercropping systems are reported to use resources higher and more efficient than monocultures. These systems could suppress weed growth due to lack of nutrients, water and solar radiation (Zimdahl, 1993; Carruthers *et al.,* 1998). Therfore, intercropping can reduce reliance of weed management on herbicide use (Liebman and Dyck, 1993; Liebman and Davis, 2000; Poggio, 2005).

Redroot pigweed is one of the most common weeds in corn, soybean, sugar beet and sunflower fields with a C_4 photosynthetic pathway. It is one of the first weeds whose herbicide resistant biotypes have been observed in the fields (Holm *et al.,* 1996). In the past two decades jimson weed has been increasingly troublesome for *solanaceous* crops such as potato, pepper, tobacco and tomato, also causing severe reduction in the yield of soybean and corn. It prefers rich soils and plentiful rainfall but can survive in sandy pastures and many severe conditions. Jimson weed is almost dispersed by seed. It is, however, a very strong (heavy) seed producer, and well-nourished which is capable of producing up to 25,000 seeds. It mainly appears in corn, soybean and sunflowers fields (Holm *et al.,* 1996).

Wheat/chickpea intercropping significantly reduced yield of chickpea. However, total productivity and land use efficiency were higher in intercropping systems comparing to monocultures of either species. There was a significant reduction in weed density and biomass for the intercropping system over both monocultures. These findings suggest wheat/chickpea intercropping increases total productivity per unit area improves land use efficiency and suppresses weeds (Banik *et al.,* 2006). Carruthers *et al.,* (2000) investigated the effects of soybean or lupin seeding alone and in combination with one of three forages (annual ryegrass, *Lolium multiflorum* Lam.; perennial ryegrass, *Lolium perenne* L.; red clover, *Trifolium pratense* L.) with corn on the yield components of corn, soybean and lupin. They also examined the effects of seeding date (simultaneously with corn or with 3 weeks delay) and number of rows of large seeded legumes (one or two) between the corn rows. Results showed that the corn kernel yield was generally not affected by any intercrop treatments, although in the first experiment some simultaneously seeded treatments resulted in decreased yields. Soybean grain yield was decreased by most treatments, although some simultaneous seeding produced yields similar to soybean monocultures. The corn harvest index was not affected by any intercrop treatments.

The main objective of the research was to determine the role of corn/soybean intercropping in the resources use efficiency and suppression of weeds as compared to their monocultures.

MATERIALS AND METHODS

The experiment was conducted during the growing season of 2006 at the research field of the Agricultural Faculty, University of Tehran (35˚ 59́N, 50˚ 75́E; 1313m above sea level). Treatments were arranged in a factorial experiment based on a randomized complete block design with three replications. The climate of the region is cold and semi-arid, with a mean annual rainfall of 240 mm mainly occurring in the spring and fall. The soil texture was clay loam with: EC= 0.68 (dS/m), pH= 7.4, O.C= 0.61 %, total N= 0.08%, P= 22.8 ppm and K= 140 ppm.

In spring, after seedbed preparation, according to conventional practices, corn (*Zea mays* L.) (K.SC. 500 cultivar) and soybean (*Glycine max* L.) (Williams cultivar) seeds were sown. The treatments consisted of 5 different mixing ratios of corn and soybean including: 100% corn: 0% soybean (P_1), 75% corn: 25% soybean (P_2), 50% corn: 50% soybean (P_3), 25% corn: 75% soybean (P_4) and 0% corn: 100% soybean (P_5). The weed infestation treatment consisted of: weed free (W_1), redroot pigweed (W_2), jimson weed (W_3) and simultaneous presence of redroot pigweed and jimson weed (W_4).

The redroot pigweed and jimson weed seeds were collected the past year from the surrounding research site and were kept at 4º C. Each plot had 6 rows with 60 cm inter row space. Plant arrangements of corn and soybean were 20 x 60 cm and 25 x 60 cm, respectively. They were sown on the same date. The weeds were sown 15 cm apart from crops on both sides of the rows, at high density on the crop sowing date. They were thinned to 15 plants per meter of the row at the two leaf-stage of each species. The field was irrigated with 7 days intervals. At the end of the growing season, all plants in the 4 rows of 2 m were harvested in each plot in order to evaluate the crop yield and weed biomass. At the same time, 10 plants of each crop and weed were selected to determine the yield components and the total biomass of weeds. Data were subjected to general linear model (PROC GLM) and means were separated (calculated) by Duncan's multiple range test (P=0.05) using SAS (SAS Institute Inc, 2002). To investigate yield advantages in pure stand and corn/soybean intercrop, land equivalence ratios (LER) were calculated.

RESULTS AND DISCUSSION

Corn Yield

The results showed significant effects made by mixing ratios of corn and soybean and weed infestation (P<0.001) along with significant interaction effects (P<0.01). The highest yield (9627.8 kg ha^{-1}) was obtained in P_2W_1 and lowest (3916.5 kg ha^{-1}) in P_4W_4 (Table 1 and Figure 1). The presence of both weed species had the highest effect on corn yield reduction. Yield reduction in treatments with low density of corn (P_4) is due to two reasons. First, low number of plants (low corn density) and second, increased competition efficiency of weeds in the plots infested with two weed species for light interception and water and nutrients absorption.

In many intercropping experiments, consisting of legume and grass, higher yields were observed compared to monocropping (Morris & Garrity, 1993). In a legume/cereal intercropping, the nitrogen of the associated crop may be improved by direct nitrogen transfer from the legume to cereal (Banik *et al.,* 2006). Legumes have adaptability to different cropping patterns and the ability to fix nitrogen, which may offer opportunities to sustain increased productivity (Jeyabal & Kuppuswamy, 2001). Therefore, productivity is potentially enhanced by the inclusion of a legume in a cropping system (Maingi *et al.,* 2001). Legume intercrops are also potential sources for plant nutrients that supplement inorganic fertilizers (Banik & Bagchi, 1994; Banik *et al.,* 2006). Li *et al.,* (2001) showed that yield and nutrient uptake by intercropped wheat, maize and soybean were all significantly higher than sole wheat, maize and soybean with the exception of potassium uptake by maize. Intercropping advantages in yield are 40-70% higher in case of wheat intercropped with maize and 28-30% in case of wheat intercropped with soybean.

Row Number Per ear

Effect of mixing ratios of corn and soybean, and weed infestation on kernel row number per ear was significant (P<0.001). Also, highest row number per ear (18.33) was observed in P_4W_1 (Table 1). The results indicated that increase in the corn ratio in the mixture will decrease row number per ear. This was observed in all weed infestation treatments. By increasing the corn density, leaf area in each plant decreased and thus, assimilation rate was decreased. In this situation, intra specific competition between corn plants and inter specific competitions between corn and weeds increased. By increasing weed diversity, weed competitive ability increased, and the high resource restriction caused lower yield in P_1 compared to P_4. With respect to reduction of kernel row number per ear before pollination, it could be concluded that weeds have negatively affected the reproduction stage of corn growth.

The lowest rate (14.59) of row number per ear was obtained in P_1W_4. Results indicated that the number of grains per row increased, as the dominance and shading of corn decreased. By using complementary pattern and good interaction between plant components in intercropping, more light was captured, and water and nutrients were absorbed compared to monocropping. In intercropping, the crop resource use occurred earlier and more efficiently than weeds (Liebman & Dyck, 1993).

Kernel Number Per row

Results showed that different mixing ratios and weed infestation had a significant effect on kernel number per row (P<0.001). Also, mean comparisons showed that the highest amount of kernel number per row (39.17) was obtained in P_4W_1 and the lowest (15.63) in P_1W_4 (Table 1), which expresses that increasing corn population decreased kernel number per row due to lower fecundation. In high corn density the competition between corn plants increased. Also, for the reason of shading in the flowering stage, reduced pollination may produce infertile flowers (Allen, 1983). Besides, lake of sufficient assimilate for filling the kernel, decreased the total number of fertile flowers in P_1W_4 treatment. Carruthers *et al.,* (2000) reported that there were no differences in the kernel number per row between intercropping and monocropping. Results of mean comparison demonstrated different effects of corn and soybean ratios on kernel number per row in different weed infestations, in such a manner that increasing the corn density from P_4 to P_1 decreased kernel number per row in all weed infestation treatments (Table 1). This can be due to increase of corn intra specific competition. Corn kernel number per row in plots infested with both weed species was decreased compare to one species infested and weed free plots This result could be attributed to more efficient resources captured at high inter specific competition of two weed species with the corn.

1000 kernel weight

All mixing ratios of corn/soybean and weed infestation significantly influenced the corn 1000 kernel weight (P<0.001). Highest amount of 1000 kernel weight (265.20 g) was seen in P_4W_1 and the lowest (214.0 g) was in P_1W_4 (Table 1). By increasing corn ratio in intercropping, the amount of 1000 kernel weight decreased (Table 1). This is due to corn intra specific competition. On the other hand, presence of both weeds caused a more efficient use of light and other resources than the crop. Diminishing kernel size was due to the competition for resource use. According to Hayder *et al.,* (2003) there was no significant effect on thousand kernel weight of corn when intercropped with soybean at any seeding rate.

Harvest Index

Corn harvest index was significantly affected (P<0.001) by all mixing ratios and weed infestation. The highest corn HI (0.45) was seen in P_2W_1 and lowest (0.20) in P_4W_4 (Table 1). In high density of weeds, harvest index decreased because of competition between plants, (Tetio Kago and Gardner, 1988) but Carruthers *et al.,* (2000) reported that intercropping didn't affect corn harvest index. Mean comparison results revealed that at different levels of weed infestation, by increasing corn ratio in intercropping, HI raises due to the increase in corn density. Lower HI in 100% corn, comparing to 75% corn treatment is due to intra specific competition and more resource allocation to vegetative growth. Hence, plant allocates less resource to reproductive growth and grain yield.

Table 1. Mean comparison of mixing ratios and weed infestation on corn yield and yield components

Weed infestation	Mixing ratios	Yield (kg ha^{-1})	Row number per ear	Kernel number per row	1000 kernel weight (g)	Harvest Index
W_1	P_1	8233.4b	17.53a	20.17c	230.43c	0.42b
	P_2	9627.7a	17.72a	24.11b	251.53b	0.45a
	P_3	8122.2b	18.23a	25.44b	253.23b	0.36c
	P_4	5705.5c	18.33a	39.17a	265.20a	0.30d
W_2	P_1	7461.1a	15.92b	18.89c	217.90c	0.32ab
	P_2	7622.2a	16.49ab	19.77c	242.57b	0.34a
	P_3	6622.2b	17.42ab	24.57b	243.63b	0.30b
	P_4	5411.3c	17.74a	27.80a	253.33a	0.25c
W_3	P_1	7733.0b	16.67a	19.85d	230.43c	0.36a
	P_2	8477.8a	17.02a	22.50c	243.60b	0.39a
	P_3	6872.2c	17.60a	25.70b	245.07b	0.32b
	P_4	5772.3d	17.75a	28.67a	262.47a	0.30b
W_4	P_1	6666.7a	14.59b	15.63c	214.00d	0.26b
	P_2	7066.7a	16.23ab	19.57b	224.00c	0.29a
	P_3	5395.0b	16.63a	21.90b	232.85b	0.24c
	P_4	3916.7c	17.54a	27.57a	252.13a	0.20d

Means with the same letter at each column are not significantly different ($P< 0.05$) based on DMRT. (W_1): weed free, (W_2) redroot pigweed, (W_3) jimson weed and (W_4), simultaneous presence of redroot pigweed and jimson weed. ($P_{1)}$ 100% corn (P_2) 75% corn (P_3) 50% corn, (P_4) 25% corn

Soybean Yield

Mixing ratios of corn and soybean along with weed infestation significantly influenced soybean grain yield (P<0.001). Also, the interaction effect between two factors was significant (P<0.001). Results indicated that in all weed treatments, sole soybean had higher yield than intercropping treatments (Table 2) which was due to higher soybean density and no competition with the corn. By lowering soybean ratio in intercropping, soybean yield was reduced because of competition. Soybean has less competitive ability than corn in intercropping systems. Naturally soybean allocates part of its resources to symbiosis association. Redroot pigweed and jimson weed infestations caused greatest soybean yield reduction in different ratios of intercropping. Simultaneous infestation of both weed species have more competitive ability with soybean than one species infestation and caused reduction in pod number per plant, grain number per pod, 1000 grain weigh, and finally caused more yield reduction. Banik *et al.,* (2006) confirmed that higher grain yield of monocropped wheat and chickpea relate to intercropping treatments may be due to the fewer disturbances in the habitat with homogeneous conditions of monocropping systems. Highest amount of yield (5050.0 kg ha^{-1}) was seen in P_5W_1 and lowest (365.67 kg ha^{-1}) in P_2W_4 (Table 2 and Figure 2).

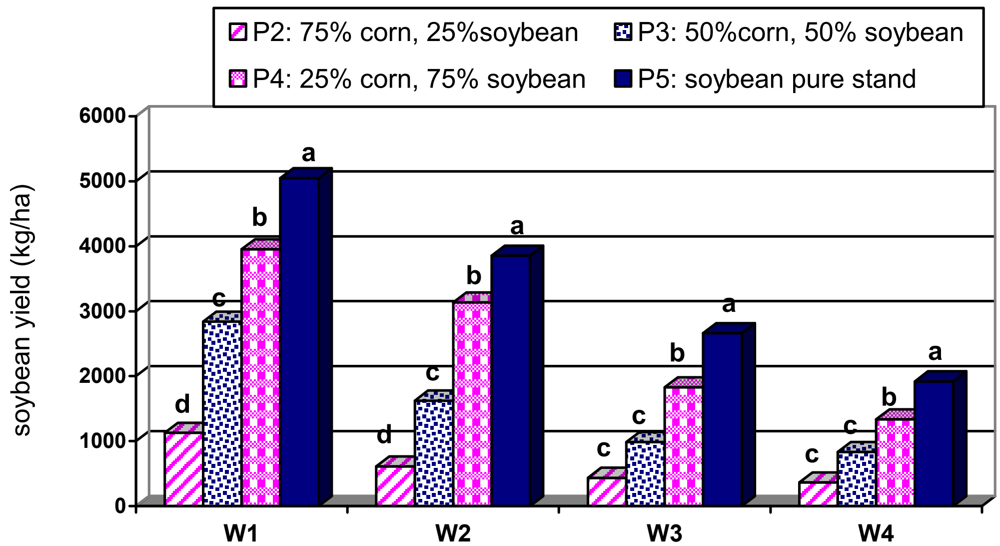

Figure 2. Interaction effect of mixing ratios and weed infestation on soybean yield. (W1): weed free, (W2): redroot pigweed, (W3): jimson weed and (W4): simultaneous presence of redroot pigweed and jimson weed

Pod Number Per Plant

Results showed significant effect by mixing ratios, weed infestation and their interaction effects ($P<0.01$). The highest amount of pod number per plant (46.85) was seen in P_5W_1 and lowest (20.39) in P_2W_4 (Table 2). The main reason for reduction of pod number per plant in P_2W_2 was the low soybean density. Of course, low ability of soybean in competition with redroot pigweed and jimson weed has an important role in diminishing this trait. Hume *et al.,* (1985) reported that, among yield components, number of pods per plant is the most closely related with soybean yield and hence the most affected factor by competition. Carruthers *et al.,* (2000) have also reported a decreased production of pods per plant in intercropped soybean relative to it's pure stand.

Grain Number Per Pod

Results revealed that the effect of mixing ratio and weed infestation on grain number per pod was significant, while their interaction effect wasn't significant. The highest amount (3.10) was observed in P_5W_1 and the lowest (2.27) was in P_2W_4. In all treatments, by diminishing the soybean ratio in intercropping, the grain number per pod decreased. This reduction is due to low competitive ability of soybean compared to corn. It could be concluded that soybean produced low grain number per pod because of changed light spectral quality and decreased light intensity under intense shade of corn canopy. Results indicated that according to morphology and competitive characteristics of redroot pigweed, the soybean grain number per pod in different mixing ratios could not be affected significantly. Jimson weed expanded most part of its leaf area above soybean canopy (data not shown) and thus prevented the light interception to soybean (Rengnier & Stoller, 1989). Carruthers *et al.,* (2000) have also emphasized on lower soybean grain number per pod at intercropping.

1000 Grain Weight

There was significant difference in mixing ratios and weed infestation for 1000 grain weight of soybean (P<0.001). The highest 1000 grain weight (112.13 g) was seen in P_5W_1 and lowest (77.27 g) was in P_2W_4. By decreasing soybean ratio in intercropping, the 1000 grain weight diminished in all weed infestation treatments. This reduction was due to corn shading on soybean. In 25% of soybean ratio, corn shading on soybean caused reduction of spectral quality and quantity of intercepted light by soybean. Actually, increasing diversity of weeds, decreased soybean ability for nutrient uptake and water absorption, and then decreased soybean grain weight.

Hayder *et al.,* (2003) had also reported similar results. These results may be due to competition between two weed species and soybean which affected soybean growth. This finding is in agreement with Thiyaga/rajan (1994), who reported a significant decrease in 1000 grain weight of the intercropped soybean.

Harvest Index

Mixing ratio, weed infestation and their interaction had significant effect on soybean harvest index. The lowest amount of HI (17.00) was seen in P_2W_4 and highest (49.01) was in P_5W_1 (Table 2). The reduction is due to corn shading effects on soybean, which causes soybean to allocate it's assimilate to vegetative growth and height increasing for competing with corn. More weed shading causes more decrease in soybean photosynthates. Carruthers *et al.,* (2000) reported that HI was not affected by intercropping, which indicates that the overall partitioning of resources within the soybean plant was not affected.

LER

According to quantity of land equivalence ratio in all treatments, corn/soybean intercropping was superior to their pure stand (LER>1). LER values indicated that yield advantages in all mixing ratios are referred to crop complementarities. Corn-soybean intercrops have frequently out yielded monocrop corn (Carruthers *et al.,* 2000). The lowest LER (1.05) was obtained in P_2W_3 and the highest (1.64) was seen in P_4W_2 (Table 2). Intercropping that consistently results in higher LERs are thought to be more efficient from a land use perspective than moncropping.

Weed Biomass

Different mixing ratios and weed infestation had significant effect on weed biomass. Result showed that the lowest amount of weed biomass (162.00 g m^{-2}) was obtained in the P_3W_2 treatment and the highest (376.73 g m^{-2}) in P_5W_4 treatment (Figure 3). The results emphasis on high interaction effects of weed infestation and corn/soybean intercropping. Less dry matter and density of weed under intercropping may be due to the suppression of the weed against monocropping. Researchers have reported that the performance of intercropping compared to sole cropping is enhanced by improvement in N fertility, moisture availability, and reduction in weed competition (Weil & Mcfadden, 1991). Intercrops may demonstrate advantages on weed control to sole crops by producing greater crop yield and less weed growth by limiting resources to weeds and also by suppressing weed growth through allelopathy (Banik *et al.,* 2006).

The reduction of weed growth through the crop interference, has been referred as one determinant of yield advantage of intercropping, being a viable alternative to reduce the reliance of weed management on herbicide use (Liebman & Dyck, 1993; Liebman & Davis, 2000; Poggio, 2005).

It is concluded that intercropping can be used as a tool to improve competitive ability of a canopy with good suppressive characteristics. As observed, the highest rate of corn yield in intercropping system (9627.8 kg ha^{-1}) was in P_2W_1 treatment, whereas the highest weed biomass (376.73 g m^{-2}) was in P_5W_4 treatment (soybean monocropping) and lowest weed biomass(162.00 g m^{-2}) obtained in P_3W_2. Interaction between crops and weeds need to be studied in more details and applying an ecophysiological crop growth model is suggested to optimize the intercrop mixtures with respect to yield, quality and suppression ability of the crops against weeds.

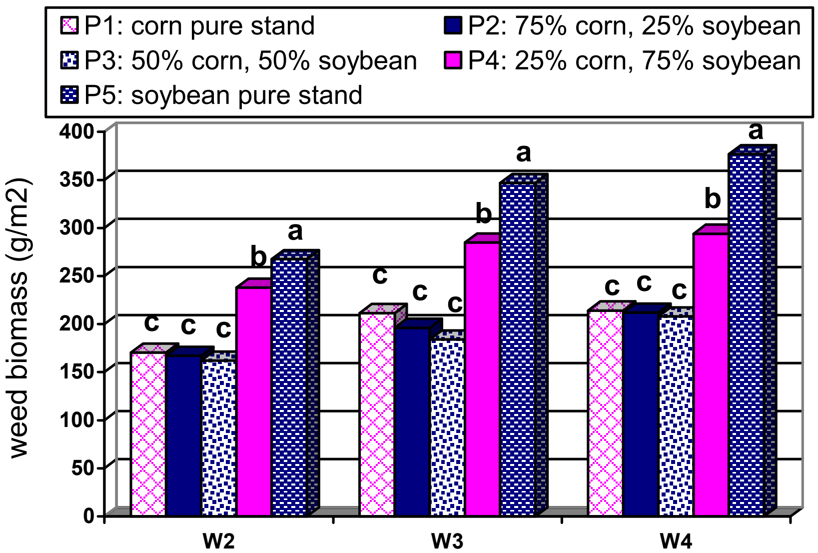

Figure 3. Interaction effect of mixing ratios and weed infestation on weed biomass. (W2): redroot pigweed, (W3): jimson weed and (W4): simultaneous presence of redroot pigweed and jimson weed

Table 2. Mean comparison of mixing ratios and weed infestation on LER and soybean yield and yield components

Weed infestation	Mixing ratios	Yield (kg ha^{-1})	Pod number per plant	grain number per pod	1000 grain weight (g)	Harvest Index	LER
W_1	P_1	-	-	-	-	-	-
	P_2	1128.96d	36.38d	2.80b	93.20c	25.71d	1.40b
	P_3	2840.83c	39.07c	2.87ab	98.80bc	29.93c	1.55a
	P_4	3955.83b	43.70b	3.03ab	102.33b	43.64b	1.48a
	P_5	5050.0a	46.85a	3.10a	112.13a	49.01a	-
W_2	P_1	-	-		-	-	-
	P_2	612.92d	29.62c	2.49a	87.93b	21.65d	1.15c
	P_3	1624.17c	36.52a	2.60a	95.50a	24.52c	1.44b
	P_4	3135.0b	37.37a	2.80a	96.73a	28.64b	1.64a
	P_5	3855.0a	37.84a	2.93a	98.50a	37.14a	-
W_3	P_1	-	-		-	-	-
	P_2	435.8c	25.77b	2.33c	82.17b	18.99b	1.05c
	P_3	987.5c	33.77a	2.46c	92.33a	23.36b	1.32b
	P_4	1830.8b	33.84a	2.70b	94.00a	28.17a	1.46a
	P_5	2663.3a	34.83a	2.93a	95.93a	31.98a	-
W_4	P_1	-	-	-	-	-	-
	P_2	365.67c	20.39c	2.27b	77.27b	17.00c	1.25a
	P_3	831.7c	23.25b	2.33b	82.87b	21.79b	1.37a
	P_4	1337.5b	31.76a	2.63a	89.67a	24.38ab	1.32a
	P_5	1920.0a	32.33a	2.83a	94.50a	26.92a	

Means with the same letter at each column are not significantly different ($P< 0.05$) based on DMRT. (W_1): weed free, (W_2) redroot pigweed, (W_3) jimson weed and (W_4): simultaneous presence of redroot pigweed and jimson weed.), (P_1) 100% corn (P_2) 75% corn (P_3) 50% corn, (P_4) 25% corn:

REFERENCES

Allen, J. R. 1983. Leaf number and maturity in hybrid corn. *Agronomy Journal.* **65**: 233-235.

Altieri, M. A. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystem and Environment*. **74**: 19–31.

Banik, P. and Bagchi, D. K. 1994. Evaluation of rice (Oryza sativa) and legume intercropping in upland situation of Bihar plateau. *Indian Journal of Agricultural Sciences.* **64**: 364–368.

Banik, P. Midya, A., Sarkar, B. K. and Ghose, S. S. 2006. Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering. *European Journal of Agronomy*. **24**: 325–332.

Brummer, E. C. 1998. Diversity, stability, and sustainable *American agriculture. Agronomy Journal*. **90**: 1–2.

Baumann, D. T., Kropff, M. J. and Bastiaans, L. 2000. Intercropping leek to suppress weeds. *Weed Research*. **40**(4): 359-374.

Carruthers, K. Prithiviraj, B., Cloutier, Q. Fe. D., Martin, R.C. and Smith, D. L. 2000. Intercropping corn with soybean, lupin and forages: yield component responses. *European Journal of Agronomy*. **12**: 103-115.

Carruthers, K., Cloutier, Fe. and Smith, D. L. 1998. Intercropping corn with soybean, lupin and forages: weed control by intercrops combined with interrow cultivation. *European Journal of Agronomy*. **8:** 225-238.

Evans, L. T. 1998. Feeding the Ten Billion, Plants and Population Growth. Cambridge University Press, Cambridge.

Exner, D. N. and Cruse, R.M. 1993. Interseeded forage legume potential as winter ground cover, nitrogen source, and competition. *Journal of Production of Agriculture*. **6**: 226–231.

Fukai, S. and Trenbath, B. R. 1993. Processes determining intercrop productivity and yields of component crops. *Field Crops Research*. **34**: 247–271.

Giller, K.E. Cadisch, G. 1995. Future benefits from biological nitrogen fixation: an ecological approach to agriculture. *Plant Soil.* **174:** 225–277.

Hauggaard-Nielsen, H. Andersen, M. K., Jørnsgaard, B. and Jensen, E. S. 2006. Density and relative frequency effects on competitive interactions and resource use in pea–barley intercrops. *Field Crops Research*. **95**: 256–267.

Hauggaard-Nielsen, H., Ambus, P. and Jense, E. S. 2001. Interspecific competition, N use and interference withweeds in pea-barley intercropping. *Field Crops Research*. **70**: 101-109.

Hayder, G., Mumtaz, . S. S., Khan, A. and Khan, S. 2003. Maize and soybean intercropping under various levels of soybean seed rates. *Asian Journal of Plant Science*. 2(3): 339-341.

Holm, L. Doll, J. Holm, E. Pancho, J. and Herberger J. 1996. World weed, natural histories and disribution. John wiley & sons, Inc.

Hume, D. F., Shanmugasundaram, S. and Beversdorf, W. I. D. 1985. Soyabean (Glycine max (L.) Merrill). In: Summerfield R.J., Roberts, E.H. (Eds.), Grain Legume Crops. William Collins, London, pp. 391–432.

Jeyabal, A. and Kuppuswamy, G. 2001. Recycling of organic wastes for the production of vermicompost and its response in rice–legume cropping system and soil fertility. *European Journal of Agronomy*. **15**: 153–170.

Li, L., Sun, J., Zhang, F., Li, X., Yang, S. and Rengel, Z. 2001. Wheat/maize or wheat/soybean strip intercropping, I. Yield advantage and interspecific interactions on nutrients. *Field Crops Research*. **71**: 123-137.

Liebman, M. and Dyck. E. 1993. Crop rotation and intercropping strategies for weed management. *Ecology Applied*. 3(1):92-122.

Liebman, M. and Davis, A. S. 2000. Integration of soil, crop and weed management in low-input farming systems. *Weed Research*. **40**: 27– 47.

Maingi, M. J., Shisanya, A.C., Gitonga, M. N. and Hornetz, B. 2001. Nitrogen fixation by common bean (Phaseolus vulgaris L.) in pure and mixed stands in semi arid South east Kenya. *European Journal of Agronomy*. **14**: 1–12.

Marchiol, L., Miceli, F., Pinosa, M. and Zerbi, G. 1992. Intercropping of soybean and maize for silage in northern Italy. Effect of nitrogen level and plant density on growth, yield, and protein content. *European Journal of Agronomy*. **1:** 207–211.

Martin, R. C., Voldeng, H. C. and Smith, D. L. 1990. Intercropping corn and soybean in a cool temperate region: yield, protein and economic benefits. *Field Crops Research.* **23**:295–310.

Morris, R. A. and Garrity, D. P. 1993. Resource capture and utilization in intercropping: non-nitrogen nutrients. *Field Crops Research*. **34**: 303-317.

Poggio, S. L. 2005. Structure of weed communities occurring in monoculture and intercropping of field pea and barley. *Agriculture, Ecosystem and Environment*. **109**: 48–58.

Regnier; E. E. and Stoller, E. W. 1989. The Effects of Soybean (Glycine max) Interference on the Canopy Architecture of Common Cocklebur (Xanthium strumarium), Jimsonweed (Datura stramonium), and Velvetleaf (Abutilon theophrasti). *Weed Science*. **37**: 187-195.

SAS Institute, 2002. SAS User's Guide: Statistics. Version 8, SAS Institute, Cary, North Carolina, USA.

Singh, N. B., Singh, P.P. and Nair, K. P. P. 1986. Effect of legume intercropping on enrichment of soil nitrogen, bacterial activity and productivity of associated maize crops. *Experimental Agriculture*. **22**: 339–344.

Tetio-Kagho, F. and Gardner, F. P. 1988. Response of maize to plant population. II: Reproductive development on yield and yield adjustment. *Agronomy Journal* **80**: 935-945.

Thiyagarajan, C. R. 1994. Studies on the quality of seeds of component crops in maize based intercropping. *Madras Agricultural Journal*. **81**: 46-47.

Van Kessel, C. and Hartley, H. 2000. Agricultural management of grain legumes: has it led to an increase in nitrogen fixation. *Field Crops Research*. **65**: 165-181.

Vandermeer, J. 1989. The Ecology of Intercropping. Cambridge University Press, Cambridge, UK.

Vandermeer, J. 1995. The ecological basis of alternative agriculture. *Annual Review Ecological Systems*. **26**: 201–224.

Vandermeer, J., Van Noordwijk, M., Anderson, J., Ong, C. and Perfecto, I. 1998. Global change and multi-species agroecosystems: concepts and issues. *Agriculture Ecosystem and Environment*. **67**: 1–22.

Weil, R. R. and Mc fadden, M. E. 1991. Fertility and weed stress effects on performance of maize/soybean intercrop. *Agronomy Journal*. **83**:717-721.

Zimdahl, R. L. 1993. Fundamentals of Weed Science. Academic Press, New York.